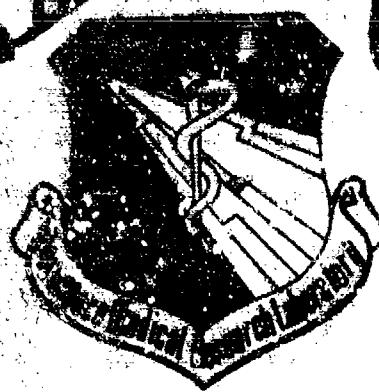


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## A PREDICTOR OF HUMAN VISUAL PERFORMANCE (PREVIP) AT FORM DISCRIMINATION TASKS

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AFAMRL-TR-69-1

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

*John P. Sturges*  
JOHN P. STURGES, COL, USAF USA  
Acting Director  
Project and Program Manager  
Air Force Aerospace Medical Research Laboratory

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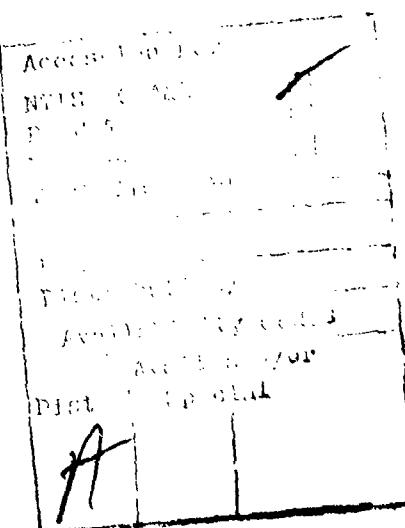
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and to test the modeling of new tasks. PREVIP accepts a digital representation of a set of visual stimuli and applies a preprogrammed visual response filter. PREVIP then uses these filter outputs to compare the stimuli against a set of previously defined prototypes. This procedure generates a distance metric upon which visual discrimination errors are predicted or against which human errors can be correlated. PREVIP can also be used to test new visual prediction tasks and visual model improvements. Improvements to be included in future versions of PREVIP are: stimulus contrast and illumination effects, masking phenomena, and peripheral visual tasks. <

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## Section 1

### INTRODUCTION

The specification of symbol sets for use in Air Force systems displays is a very subjective task. There exists no specification or military standard which can predict the intersymbol confusions generated by a human subject during a symbol recognition task.

The algorithm presented in this report is an important tool in the specification of symbol sets. PREVIP is a PREDICTOR of VISUAL Performance. It provides a measure of the suitability of a symbol set by predicting the errors that will be made by human subjects in identifying symbols on the basis of form (shape). The algorithm is also used to display the effects of spatial filters and is used as a research vehicle to test visual system models. PREVIP is modular in design, thus allowing the user to extend or modify subroutines according to his needs.

PREVIP does not predict association errors such as the confusion resulting from symbol "A" meaning truck and symbol "T" meaning aircraft (semantic error). No context rules are applied; the prediction is based solely on the shape of the symbol in the stimulus and not on its use, significance, or meaning in a particular application. The effects of stimulus contrast and illumination level are not included, and neither is the peripheral visual field.

The intent of PREVIP is to aid in the development of a specification (or military standard) for optimal symbol sets, where "optimal" is used in the sense of minimized discrimination errors by human observers.

The approach used by PREVIP is based upon a model of the human visual system designed to simulate its shape recognition mechanism (Kabrisky, 1966). The human visual system exhibits a remarkable capability to discriminate between dissimilar symbols and to group symbols which have certain similarities. This ability has been modeled by the combined efforts of several investigators (Carl and Hall, 1972; Dailey and Sutton, 1972; Gagnon, 1976; Hall, 1971;

Kabrisky, 1966; Martinelli, 1973; Radoy, 1967; Ragsdale, 1972; Tallman, 1969a, 1969b, 1970; and Thorne, 1970) in what is herein called the form recognition model of the human visual system, and which is the basis for PREVIP.

The high correlation between this model of the human visual system (HVS) and psychophysical experiments which have been reported (Ginsburg, 1971; Ginsburg et al., 1972; Goble, 1975, 1976; Maher, 1970; Ragsdale, 1972; Tallman, 1969b; and Thomas, 1972), add credence to the validity of the HVS model.

One conclusion drawn from these references is that the Euclidean distance between vectors (representing stimuli in the decision space of the model) is a good measure of the dissimilarity reported (and of the errors made) by human subjects. A second conclusion is that the appropriate use of human modulation transfer function (MTF) provides an effective decision space in which the distance metric can be applied.

The approach used in the algorithm is described by presenting the visual response function (VRF), which is based upon published and unpublished MTF data, and the Rank Correlation in subroutine RNKCOR. The remainder of the algorithm consists of a series of self-explanatory computations and data handling covered, as necessary, in the remaining sections of this report.

## Section 2 DERIVATION OF ALGORITHM

### VISUAL RESPONSE FUNCTION

The response of the visual system to certain tasks indicates the ability of the visual system to selectively place emphasis on different regions of the range of available spatial frequencies. This selective capability is the concept used to generate the visual response function (VRF) for the tasks of foveal view, peripheral view, and foveal form perception.

Consider the modulation transfer function (MTF) data presented by Cowger (1973) and by Hilz and Cavonius (1974). These data can be approximated by the following function of spatial frequency  $f$  and point of regard  $\theta$ :

$$W(f) = \frac{f}{f_0} e^{-(1-f/f_0)} e^{-\theta/7} \quad (1)$$

where

$$f_0 = 8 e^{-2\theta/30} \quad (2)$$

The point of regard is the angle between the visual axis and a point of interest in the periphery.  $W$  is the sensitivity relative to the peak of the MTF curve at a point of regard of  $\theta = 0$ .  $f_0$  is the spatial frequency of the peak of the MTF curve. Equations (1) and (2) assume a small target size at the point of regard such that  $\theta$  can be assumed constant over the size of the target.

Since  $W(f)$  is normalized,  $W(f_0) = 1$  at  $\theta = 0$ . This implies that the dependence of the visual system on illumination or contrast is not considered. These parameters are not considered because this report will address only the task of form (shape) discrimination of foveally presented stimuli under high contrast and photopic light levels.

Previous research has shown that foveal form recognition (form discrimination) is a low spatial frequency phenomenon. Equations (1) and (2) imply that the fovea ( $\theta = 0$ ) has a peak spatial frequency response at  $f = 8$  c/deg. [ $W(8) = 1$ ];  $W(16) = .736$ ,  $W(40) = .1$ , and  $W(60) = .01$ . This response indicates that the fovea is sensitive to a wide range of spatial frequencies. How then can a low spatial frequency phenomenon be found in the foveal region? This section presents a concept which provides a feasible explanation of how the high resolution fovea could be used to perform a low resolution form recognition task.

Consider the abstract concept of "field of attention" (FOA) and assume that the visual system can control the size ( $\alpha$ ) of the FOA. For purposes of this report, let the FOA be the region of visual space centered on the visual axis in which an important event is expected to occur. For peripheral events, one must pay attention to a field of attention of  $\alpha = 2n$  degrees when the stimulus is located at an eccentricity of  $\theta = n$  degrees. However, if the event occurs in the fovea,  $\theta = 0$ ,  $\alpha = 2\theta = 0$  and Equation (2) implies full foveal resolution. This is, of course, in disagreement with the foveal form recognition results found by pattern recognition experiments and by psychophysical experiments. The concept of field of attention must, therefore, be expanded beyond the  $\alpha = 2\theta$  interpretation.

Assume that the visual system can selectively use its high-resolution foveal system or its lower-resolution peripheral system depending on the visual task. The low-resolution system is not confined to the peripheral retina but also includes the foveal retina. With this assumption, the foveal form recognition reported by other investigators can be interpreted to be a low-resolution vision task performed by use of the foveal retina.

One way of visualizing this form recognition concept is to assume that the high-resolution visual system reports that the stimuli in Figure 1 are composed of line segments, asterisks, Xs, and  $\Delta$ s, respectively, while the low-resolution visual system reports that the stimuli are the letters A, B, C, and D, respectively. The visual system can report both responses for a foveal presentation, while only the low-resolution response can be reported for a peripheral presentation.

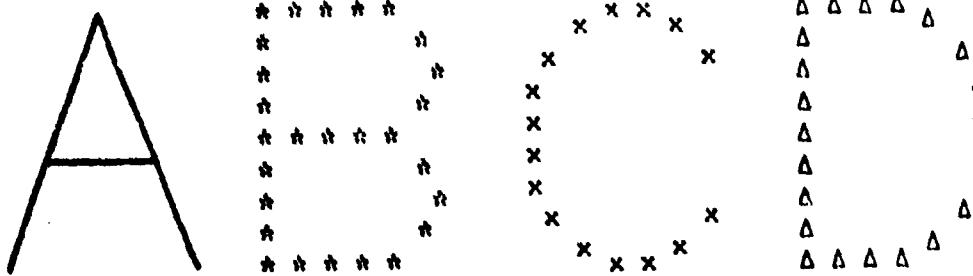


Figure 1. Typical Stimuli

The response elicited from the subject is derived from one or both of these systems depending upon the task.

The visual task which requires the report of stimulus details can be considered to require attention to "objects of interest" which are of minimum size and would require the full resolution provided by Equations (1) and (2). This effect is obtained for  $\theta$  equal to the number of degrees of visual angle between the visual axis and the stimulus (the eccentricity or point of regard).

The visual task which requires the report of form information can be considered to require attention to symbol (object) as a whole. Hence, the size of the "object of interest" is now the size of the symbol or "form" in the stimulus. Consider this size to be  $n$  degrees. The fundamental spatial frequency representing the "form" is then

$$f_1 = \frac{1}{n} \text{ c/degrees}$$

The assumption is now made that for a visual task requiring recognition of the shape of an object of size  $n$  degrees, the peak response of the visual response curve occur at

$$f_1 = 8e^{-\alpha/30} \quad (3)$$

where  $\alpha$  is the field of attention required to yield  $f_1$  as the peak of the curve.

Equations (1) and (2) are thus generalized to be

$$W(f) = \frac{f}{f_1} e^{\left(\frac{f}{1-f_1}\right)} e^{-\theta/7} \quad (4)$$

where

$$f_1 = 8e^{-\alpha/30} \quad (5)$$

If the object size of interest is less than or equal to .125 degree (fundamental frequency = 8 cycles/degree), Equations (1) and (2) satisfactorily describe the visual system filter functions. If, however, the object size is greater than .125, Equations (4) and (5) apply for a form or shape recognition task. In other words, it is hypothesized that the peak of the visual system spatial frequency filter moves to lower spatial frequencies as the object to be recognized becomes larger.

Finally, Equations (4) and (5) may be generalized by the following conditions on :

$$\alpha = \begin{cases} 30 \ln(8n) & \text{for } n > .125 \\ 2\theta & \text{for } n \leq .125 \end{cases} \quad (6)$$

(7)

$\theta$  is as defined in Equations (1) and (2).

Equations (4) through (7) represent the VRF as implemented in PREVIP. Equations (4) through (6) constitute the filter used to generate the distance matrix. This matrix predicts the distinguishability of the "form" of one stimulus from those of other stimuli and predicts the types of "form" related errors to be expected with a particular set of stimuli.

Task 0 in the computer program allows the display of the effects of the VRF on a stimulus. This display is by means of a 21 grey-level line printer printout, since a graphics terminal was not available.

Tasks 1 through 4 cause the generation of a distance matrix which contains the distance between each stimulus and each of the "prototypes" or each of the remaining stimuli. The Euclidean distance metric is used to define the distance between the vectors  $X_i$  representing the filtered stimuli and each prototype  $P_j$ . The distance between the  $i^{\text{th}}$  stimulus  $X_i$  and the  $j^{\text{th}}$  prototype  $P_j$  is

$$d_{ij} = \sqrt{\sum_{n=1}^N (x_{ni} - p_{nj})^2} \quad (8)$$

where  $N$  is the number of components in the vector and the lower case  $d$ ,  $x$ , and  $p$  are used to refer to elements of a vector or array.

The distance matrix  $D$  is the basic output from PREVIP. It contains the net result of the filtering performed by the VRF. If the VRF is, in fact, related in some manner to form recognition, we should expect this distance matrix to be correlated with human errors. This correlation is performed by subroutine RNKCOR if human response data is available.

#### CORRELATION WITH HUMAN RESPONSES

PREVIP computes the correlation between the prediction implied by the distance matrix  $D$  and the human response data contained in matrix  $H$ . This correlation computation is performed in subroutine RNKCOR after the distance matrix  $D$  has been converted by subroutines PROBDS and PRCON to a proximity matrix or to a probability matrix. The choice of a proximity matrix was made because sufficient probabilistic information on the process being modeled does not exist. When probability conversions are available, subroutine PRCON can be modified to relate distance  $d_{ij}$  to the appropriate probability of error. As presently implemented, PRCON changes  $d_{ij}$  to

$$d_{ij}^1 = \begin{cases} 1 - d_{ij} & \text{for } d_{ij} \leq 1 \\ 0 & \text{for } d_{ij} > 1 \end{cases} \quad (9)$$

which is a measure of proximity of each stimulus  $X_i$  to each prototype  $P_j$ .

The human responses from a psychophysical experiment are stored in matrix  $H$  and converted to a probability of error matrix by dividing each element of each row by the total number of responses in that row. Note that each row contained the responses for a particular stimulus. The elements on the main diagonal of the matrix now contain the probability of correct response which are now set to zero to yield a probability of error matrix  $H$ . The total number of errors in each element of  $H$  can be recovered by multiplying each  $h_{ij}$  by the total number of presentations per symbol.

The proximity (or probability) matrix  $D^1$  is ordered in such a manner as to place the closest prototype to each stimulus in column 1, the next closest prototype in column 2, and so forth to the furthest prototype in the last column. Array  $S$  contains the ordering sequence of prototypes for each stimulus. The elements  $d_{ij}^1$  of the ordered  $D^1$  matrix are now assigned a rank  $r_i$  as follows

$$r_j = j - 1 \quad j = 2, \dots, NP \quad (10)$$

where  $j$  is the column index and  $NP$  is the number of prototypes.

If the human response error probabilities (or number of errors) are averaged within each rank defined in  $D^1$  and as identified by the sequence array  $S$ , the number of errors as a function of rank can be plotted as shown in Figures 2 through 7.

These figures were generated using PREVIP, the data described by Goble (1975, 1976) and the human error matrix that he reported. The Goble data

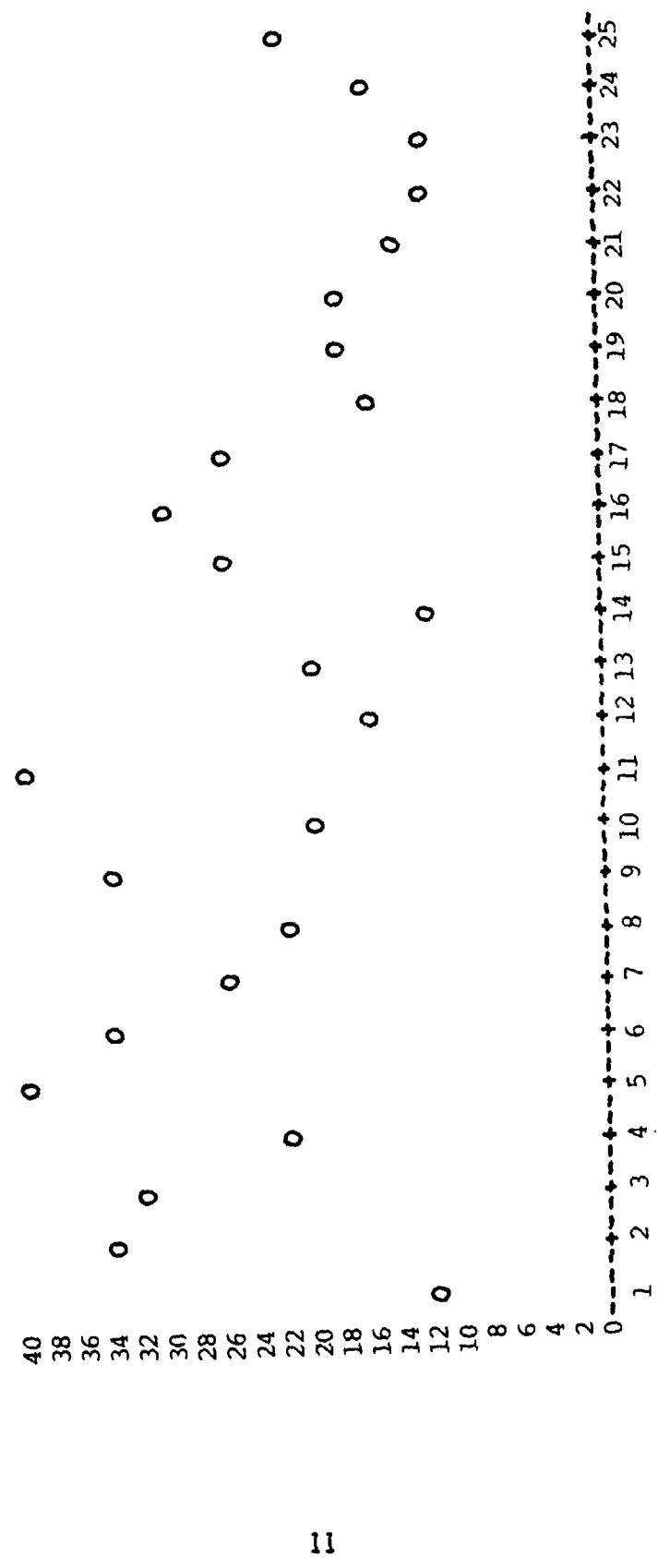


Figure 2. Correlation Between Human Errors and Predictor. (Ranks are based on interstimulus distances between alphabetic characters when task is assumed to be a detailed foveal task.)

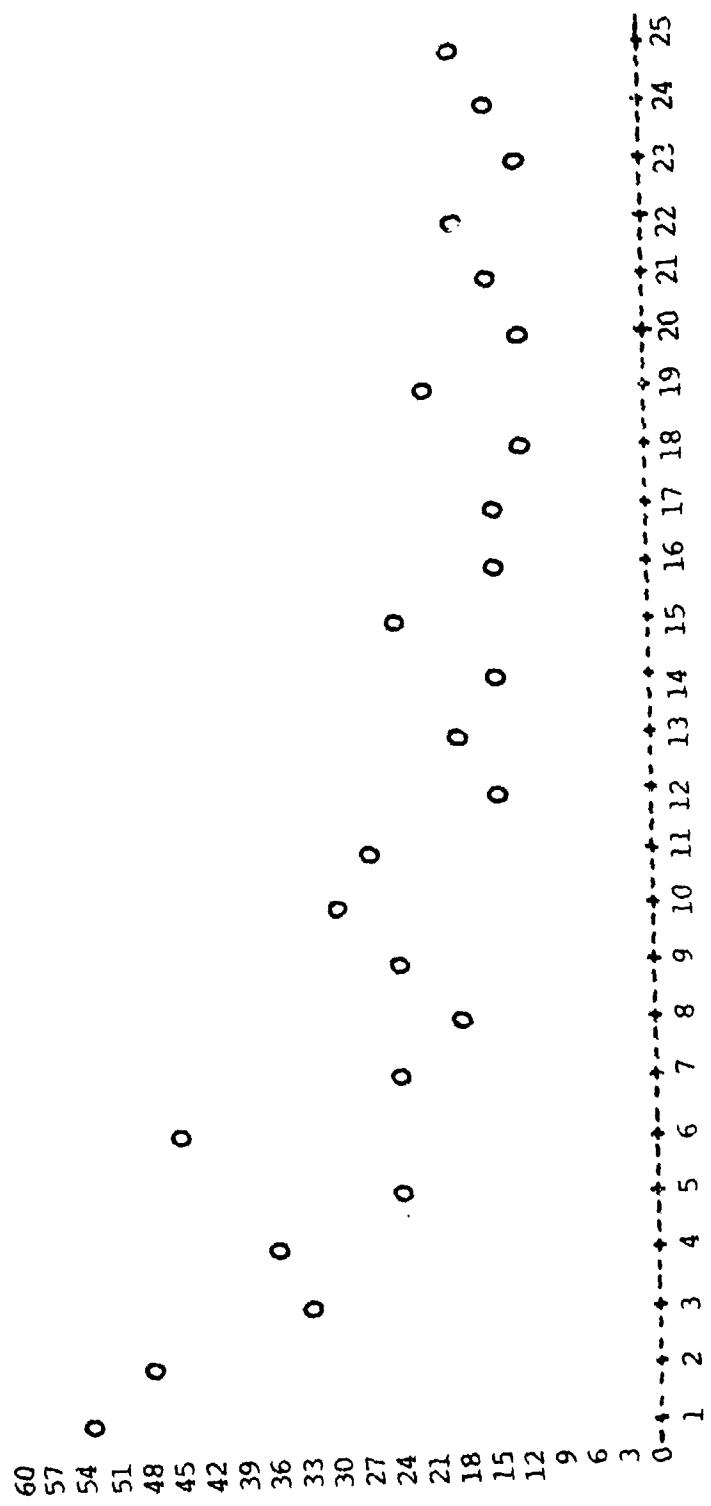


Figure 3. Correlation Between Human Errors and Predictor.  
(Ranks are based on interstimulus distances between  
alphabetic characters, Set No. 1.)

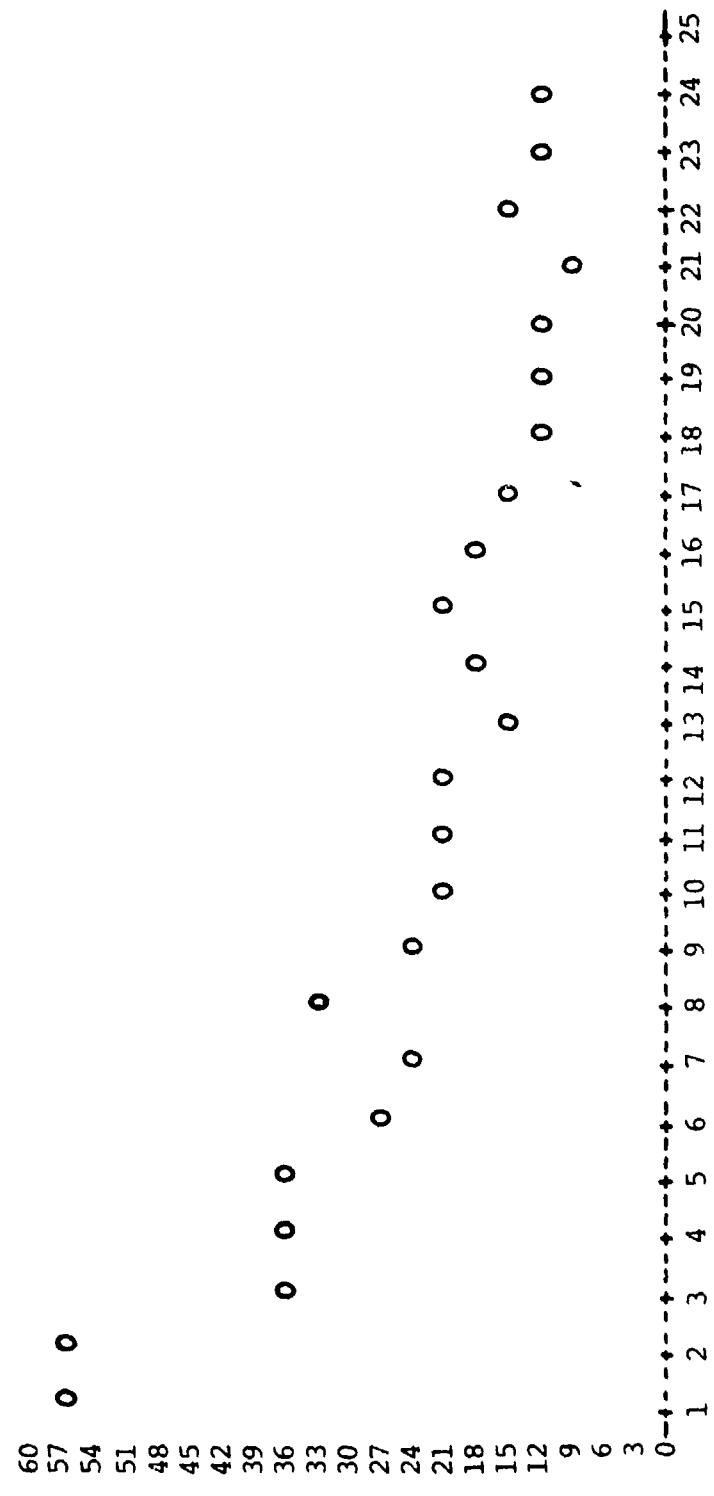


Figure 4. Correlation Between Human Errors and Predictor.  
(Ranks are based on interstimulus distances between  
alphanumeric characters, Set No. 2.)

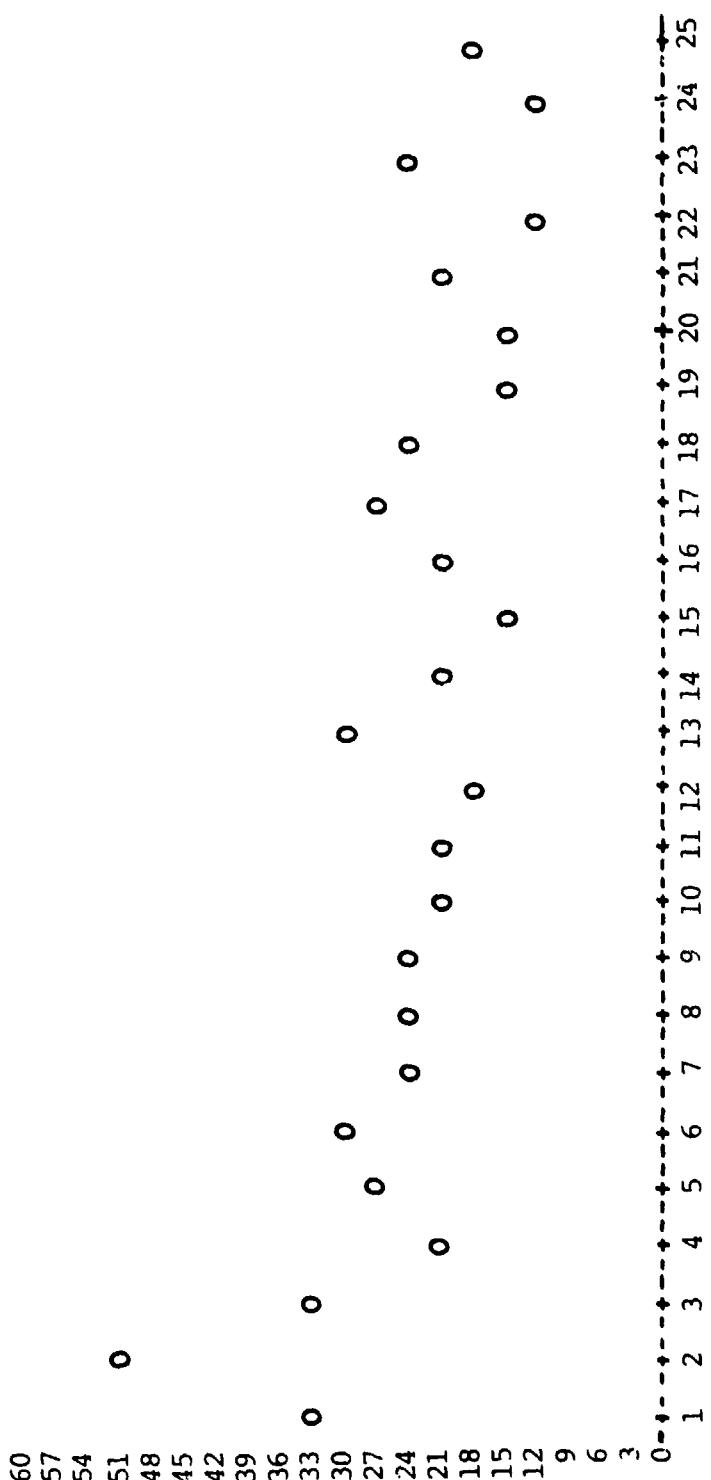


Figure 5. Correlation Between Human Errors and Predictor.  
 (Ranks are based on interstimulus distances between  
 alphabetic characters, Set No. 3.)

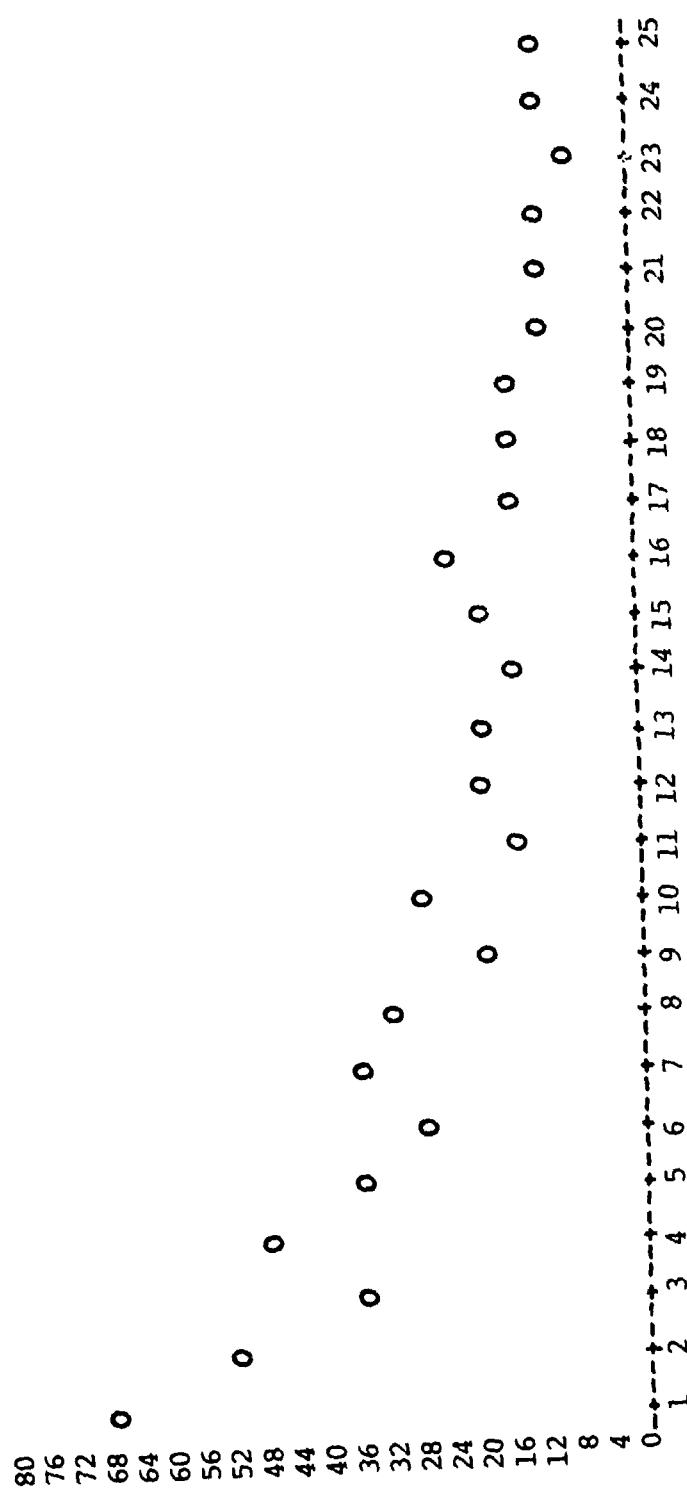


Figure 6. Correlation Between Human Errors and Predictor.  
(Ranks are based on interprototype distances.)

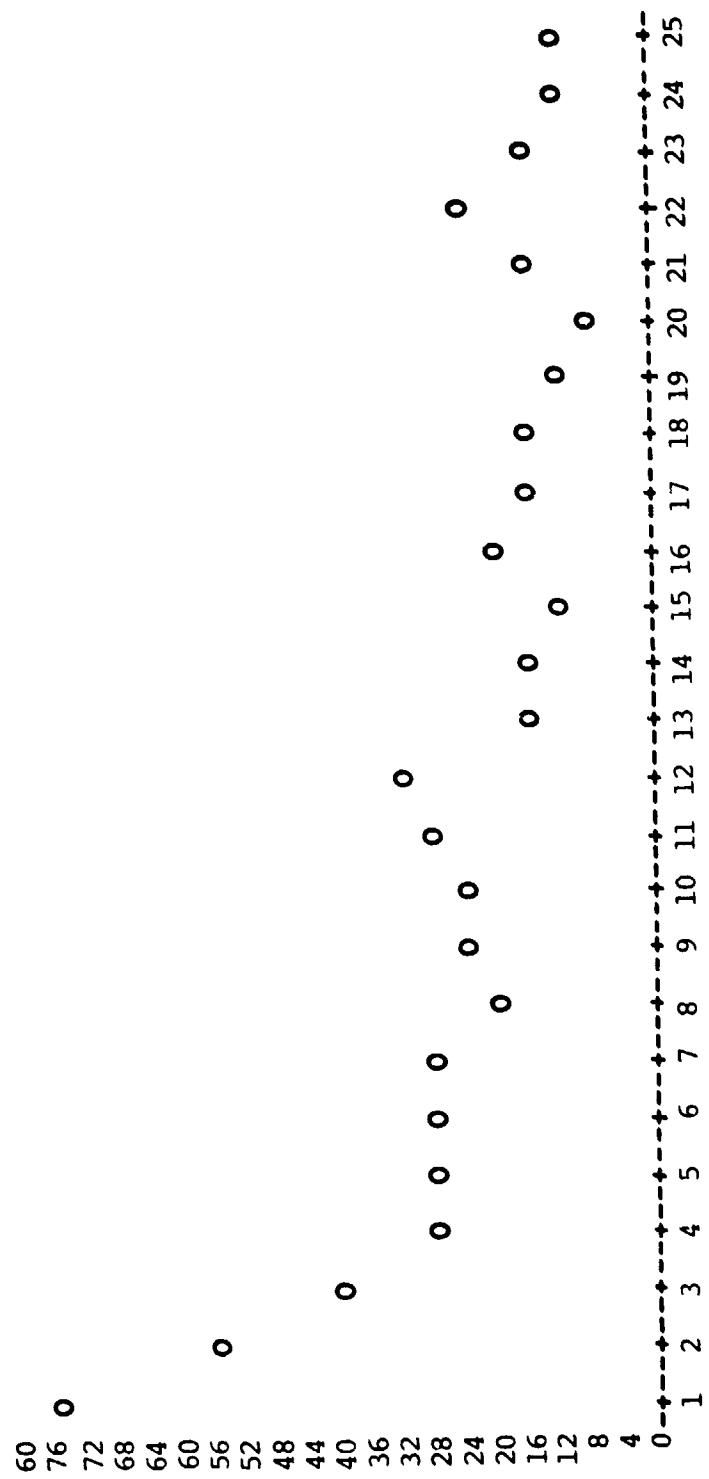


Figure 7. Correlation Between Human Errors and Predictor.  
(Ranks are based on averaged distances of each symbol from each prototype.)

set consists of 3 hand-printed versions of the alphabet in the form of isolated dots on a cathode ray tube (CRT) display. Goble presented these stimuli to a series of subjects in such a manner as to force errors. The presentations were foveal, with the character subtending 2 degrees in the field of view on a CRT display. Each symbol presentation was preceded and followed by random noise dots on the CRT display. The density of this noise was used to control the noise level in the stimulus. The human error responses were recorded, and a single matrix of errors was obtained.

This data set was used to test PREVIP and to demonstrate its use on a set of data. Figure 2 presents the results of PREVIP if one erroneously assumes that form recognition of an alphabet during a foveal presentation is a foveal vision task (i.e., a high-resolution task). In order to generate Figure 2, the following parameters were used: FOV = 3 degrees, an object of interest size of 0 degree, a symbol size of 2 degrees, and a POR of 0 degree. Note that there is no correlation between the human errors and the ranking of the distance matrix.

Assume that the same conditions apply and simply change the object of interest size to that of the symbol in the stimulus. The net effect is shown in Figure 3; here notice that the human errors are nicely correlated with the ranks defined for the distance matrix. This implies that the form recognition errors made by human subjects agree with the predictor when one considers form recognition to be a peripheral vision task as outlined above.

Figures 2 and 3 considered only one of the three versions of hand-printed letters. The distance matrix used by the predictor was generated by using the stimuli themselves as the prototypes. Also, no noise was added. The other two versions yield similar results and are shown in Figures 4 and 5.

Figures 3 through 5 demonstrate that the distance between alphabetic characters (using a single version of the characters) is reasonably effective in accounting for the errors made by people.

An improvement in the rank correlation predictions is obtained by considering prototypes formed by averaging each of the three versions of the stimuli. Figure 6 is a plot of the averaged human errors as a function of rank predicted by the model when the averaged prototypes were used in lieu of the individual stimuli. Note that Figure 6 is an improvement over the predictions of Figures 3 through 5.

Further improvement is obtained by using the individual stimuli to obtain predictions based upon their distances to these averaged prototypes. This is done by use of Task 3 in the computer program PREVIP. All three versions of the letter "A" are followed by the three versions of "B," then the three versions of "C," and so forth to the three versions of "Z." The distance matrix elements  $d_{ij}$  are formed by computing the average distance between the  $i^{\text{th}}$  symbol (e.g.,  $i = 2$  for "B") and the  $j^{\text{th}}$  prototype.

$$d_{ij} = \frac{1}{M} \sum_{k=1}^M |x_i^{(k)} - p_j| \quad (11)$$

$$= \frac{1}{M} \sum_{k=1}^M \left[ \sum_{n=1}^N (x_{in}^{(k)} - p_{jn})^2 \right]^{1/2} \quad (12)$$

where  $M$  is the number of versions,  $N$  is the number of components in the vector representing the stimuli and the prototypes. The results of rank correlating the average human errors within each rank predicted by the resulting distance matrix are shown in Figure 7.

The conclusions drawn from the above are that the distance between individual versions of a symbol set is a reasonable predictor of the errors made by people; a better predictor is the distance between averaged prototypes; and an even better predictor is the averaged distance between the individual stimuli and the averaged prototypes. The above conclusions are not surprising since the human response matrix is the result of combining the responses to the three versions of the letters.

There are several reasons not to expect perfect correlation. One reason is that the stimuli were presented with random masking noise while the model does not include noise. A second is that the predictor is not response biased while the human data is biased. The expected response of the subject is not equiprobable across all stimuli. The result is that the human response matrix contains some errors which are not related to what was seen but to what was expected or what was thought to be a good response.

#### SYMBOL SET CONFUSABILITY

The prediction of human performance, although gratifying, is not very helpful to the engineer who must determine whether or not a symbol set is suitable. The main reason is that he is interested in a symbol set which yields no errors. How close to this end can he get? Given two or more symbol sets, which one is the best? The distance matrix obtained from PREVIP can be used to supply this answer and to identify the confusability of each symbol set. The symbol set confusability is then based upon the confusability of each symbol. The confusability of the  $i^{\text{th}}$  symbol in a symbol set is defined as:

$$M_i = \sum_{\substack{j=1 \\ i \neq j}}^{NP-1} \left( \frac{1}{d_{ij}} - \frac{1}{2} \right) \quad i = 1, 2, \dots, NP$$

where  $NP$  is the number of stimuli in the symbol sets and  $0.001 \leq d_{ij} \leq 2$  is the Euclidean distance between the  $i^{\text{th}}$  and the  $j^{\text{th}}$  symbol. If  $d_{ij} < 0.001$ ,  $d_{ij}$  is set equal to 0.001 in order to keep  $M_i$  finite. The least confusable symbol would have the smallest  $M_i$  whereas the worst symbol would have the largest  $M_i$ . Symbol sets can be compared by computing the overall  $M$  for each symbol set:

$$M = \frac{1}{NP(NP-1)} \sum_{i=1}^{NP} M_i$$

The best symbol set has the smallest  $M$ .

Subroutine CONFUS implements the symbol set confusability measures. It also demonstrates the symbol set improvements obtained by removing the worst symbols.

Section 3  
COMPUTER PROGRAM\*

PREVIP INPUT

The input to PREVIP is in the form of a set of from 5 to 9 parameter cards which identify the job to be performed. The number of cards required depends upon the parameters specified on the cards. See the PARAMETER CARDS section for details on parameter card formats and entries.

The input stimuli are read in from either the card reader (logical FILE 5-TAPE 5) or from TAPE 4 which can be either formatted or unformatted. Subroutine PICK is used to input the stimuli or its filtered spatial frequency representation. The format needed to read the data is defined on the appropriate parameter cards. If the data to be read in is encoded, in order to save mass storage space or cards, the coding routine is subroutines, PICK can perform this function. A call to centering subroutine CNTS is also made by PICK to center the stimulus. This option can only be used if the stimulus is represented by a set of 1s on a background of 0s. CNTSZ is used for this purpose in the analysis of the data used to generate Figures 2 and 3. The user is expected to modify PICK in order to change these special data conditionings. The program also uses TAPE 1, TAPE 2, and TAPE 3 as temporary storage files; however, these are not allowed as input files. The user may desire to allow their use by revising PREVIP accordingly.

The human response data to be used to correlate with the predicted errors must be input as a matrix of response to a set of stimuli or as a probability of error matrix. The matrix must be organized such as to read in the responses (or probabilities of error) for each stimulus presented. The order of the responses and the stimuli must be the same; i.e., the correct response must lie on the main diagonal of the matrix. If the entries on the main diagonal are nonzero, the program assumes the matrix to be a response

\*Throughout Section 3, the symbol 0 designates the letter, and 0 designates zero.

matrix and converts the matrix to a probability of error matrix. The conversion is done by the division of each response bin for each stimulus by the total number of responses to that stimulus.

If the first main diagonal element is 999, the divisor is assumed to be 3,000. This default divisor can be changed by modification of subroutine HUMERR. After the division, the diagonal elements are set to zero and the matrix becomes an estimated probability of error matrix. If the matrix is read in with zeros on the main diagonal, the matrix is used as is to represent an estimated probability of error matrix based on human response data.

#### PREVIP OUTPUT

The output from PREVIP is in the form of printout, punched cards, and mass storage files.

##### Printout

The main output from PREVIP is a distance matrix and an ordered distance matrix followed by a statistical evaluation of the distance matrix. By the proper use of parameter card options, the correlation can be obtained between the human response errors (if available) and the error predictions based on the distance matrix. Figures 3 through 7 are examples of this correlation printout. PREVIP also presents a plot of the distribution of the elements in the distance matrix over the range of distance values from zero to two. The  $k^{\text{th}}$  distance cell contains the number of elements in the distance matrix whose distance value  $d$  lies in the range of:

$$R_k < d \leq R_{k+1} \quad k = 1, 2, \dots, 24$$

where  $R_k = R_{k-1} + 0.05$

and  $R_0 = 0$

### Punched Output

The operator can obtain a computer card copy of either the distance matrix or of the ordered distance matrix (along with its ordering sequence) by the proper use of the parameters on the DSMATX parameter card and by transferring formatted TAPE 3 to a punch file. The transfer is accomplished by use of a "COPYBF" (TAPE 3, PUNCH)" control card on the CDC 6600 computer.

### Permanent Files and Magnetic Tapes

Certain information can be saved in unformatted permanent files in mass storage or on magnetic tape reels. The vectors representing the filtered stimuli are contained in an unformatted file (TAPE 1). These vectors are those read in as a result of the "STIMUL" parameter card. They can be saved for subsequent runs by identifying TAPE 1 as a permanent file on a mass storage device or by mounting a magnetic tape and identifying it as TAPE 1. In order to use this option, the parameters on the PROBAB parameter card must be blank or zero. The main program creates this file.

The distance matrix can be saved on an unformatted file (TAPE 2) in the same manner as for TAPE 1 above. Again, PROBAB parameters must be blank or zero. Subroutine DSCOMP creates this file called TAPE 2.

The ordered distance matrix along with the ordering sequence can also be saved in an unformatted file (TAPE 3) in the same manner. Note that the file is organized with a set of NP sequence numbers in one record, followed by the NP distance ordered from smallest to largest in the next record. NP is the number of prototypes, and the distances are those between the first stimulus and each of the prototypes. The above records are repeated for subsequent stimuli. Note that if the user does not provide prototypes, PREVIP will use the stimuli as prototypes. Also, if the user does not provide stimuli, PREVIP will use the prototypes as stimuli. Note also that if TASK 3 or 4 is used, the net result is a distance matrix which has NP stimuli and NP prototypes. Subroutine ORDER creates this file called TAPE 3.

## KEY PARAMETERS

The PREVIP program makes use of a number of parameters which are important to the user who desires to modify PREVIP. When converting PREVIP to handle stimuli represented by a different size array, seven cards (PVP1 60, 80, 100, 120, 200, and 220) must be changed to agree with the new values for MJ and MI. When tailoring PREVIP to an efficient size for array PR, two cards must be changed (PVP1 80 and 480).

The parameters that are related to array dimensions are:

<u>Parameter</u>	<u>Definition of the Parameter</u>
MJ	The number of resolution elements in each row of a stimulus.
MI	The number of rows in the stimulus.
NC	The number of components in a vector.
NP	The number of prototypes.
NV	The number of vectors.
NPRC	The number of elements in the PR array. In order to make PREVIP efficient, choose NPRC = NC or NPRC = NP * NC, where NC is the number of components in the vector representing the prototypes and NP is the number of prototypes. The former choice allows one prototype to be stored in PR; the remaining prototypes are stored on tapes. The latter choice allows all prototypes to be stored in PR. The program will use TAPE 3 to store all prototypes if there is not enough room for all in PR.
MNP	The maximum number of prototypes allowed. MNP = MJ * 7 which is the dimension of the array (HDR) used to store the alphanumeric representing the stimuli.
MNV	The maximum number of vectors allowed. MNV = MJ * MI-MNP. MNV is limited by the dimensions of array LBL which is used to store the alphanumeric representing the stimuli.
TSK	The task to be performed by PREVIP. See PARAMETER CARDS section for details.

## PARAMETER CARDS

The following parameter cards are used to identify program parameters and options. Each card and its order are mandatory unless otherwise indicated. Most cards start with a six-character label in columns 1 through 6. These labels are useful in identifying user errors in organizing the data deck. The parameter card formats are as follows:

<u>Card Label</u>	<u>Columns</u>	<u>Entries on Card</u>
PROBLM	1-6	Enter "PROBLM"
	11-80	Enter title of the problem. Used to identify the run by the name of the data set and/or alternate procedures used.
TASKNB	1-6	Enter "TASKNB"
	10	Enter task number (TSK). The allowed entries are:  0--For input of visual stimuli followed by filtering and display of results in a grey scale display on the line printer.  1--For computation of prediction matrix based upon distance between stimuli and a set of prototypes. The input stimulus is assumed to be a matrix of resolution elements containing the intensity of light corresponding to the stimulus, picture, or image to be processed.  2--For the same conditions as TSK = 1 except that the input stimuli have already been filtered. The stimuli are input as a set of vectors containing NC components.  3--For same conditions as 1 except that the number of prototypes is not the same as the number of stimuli. An example is: a set of prototypes representing a set of symbols (an alphabet) and M versions (such as hand printed) of each symbol to form the set of stimuli. Under TASK 3, the M versions of the symbol represented by the first prototype are to be the first M stimuli. The next M stimuli are the M versions of the symbol represented

by the second prototype. The total number of stimuli (NV) must be  $NV = M * NP$  where NP is the number of prototypes. TASK 3 generates a square distance matrix which contains  $NP * NP$  elements. See Equation 12 in the CORRELATION WITH HUMAN RESPONSE section for distance computations used in TASK 3.

4--Same as 3 except the stimuli have already been processed and filtered. The stimuli are input as vectors containing NC components.

TASKNB	9-10	<p>-1--This task is the same as TASK Zero except that the stimuli to be displayed have been already processed, filtered, and represented as a vector. The stimuli are input as a set of vectors containing NC components. Subroutine VRF places the vector components in the proper location in a complex spatial frequency array. The inverse Fourier transform is completed and displayed using the 20 grey-scale lineprinter routine use in TASK Zero.</p> <p>NOTE: The nontitled filter parameter card (which follows next) <u>must</u> be the same as that used to generate the input vectors.</p>
	15	<p>Used only when TSK is greater than zero. Enter:</p> <p>1--If a display of the stimulus prior to filtering is desired.</p> <p>2--(Or leave blank) If a display after filtering is desired.</p> <p>3--If both displays are desired.</p>
	20	<p>Used only if TSK is greater than zero. Enter:</p> <p>0--(Or a blank) If the 20 grey-scale display of filtered stimuli is not to recompute the grey-scales used for that display. The grey-scales defined prior to filtering are used. If the prefilter display was not performed (a blank or a 2 in column 15), the grey-scales are computed.</p> <p>1--If the minimum and maximum intensities of each filtered stimulus are to be recomputed and grey-scales adjusted accordingly.</p>

	19-20	<p>-1--Same as 1 except the negative of the stimulus is displayed. For example, one would represent a handprinted letter as an array of 1s on a background of zeros (or blanks) in a set of cards. The 1s represent high intensity whereas the zeros (blanks) represent black. The display is then a white letter or a black background. The -1 in column 19-20 yields a black letter on a white (blank) background.</p> <p>-2--Same as zero except the negative of the stimulus is displayed.</p>
NEW CARD NO TITLE	1-5	Enter the horizontal field of view FOV (1) (in degrees of visual angle) subtended by the stimulus array. Use F-format.
	6-10	Enter the vertical field of view FOV (2) subtended by the stimulus array. Use F-format.
	11-15	Enter the size of the object of interest (in degrees of visual angle). Use F-format. This parameter identifies the size of the object of interest in the field of view. The size must be approximately that of the symbol, character, or letter in the field of view if prediction of human performance is expected or desired.
	16-20	Enter the point of regard (POR) in F-format. The point of regard defines the location of the stimulus, in degrees of visual angle, relative to the visual axis. POR is to be left blank or set equal to zero when the program is used to predict human performance. When POR is properly tested, its use at non-zero values will be recommended to predict human performance at form recognition tasks using the peripheral retina.
PROTYP	1-6	Enter "PROTYP"
	7-10	<p>The number of prototypes NP to be used. Right justify to column 10.</p> <p>0--(Or a blank) For TSK = 0 or TSK less than zero.</p> <p>+NP--Enter a positive NP when TSK is greater than zero and a set of prototypes is available which represents a set of symbols, characters, or shapes.</p>

-NP--Enter a negative NP when TSK is greater than zero and a set of prototypes is not available. PREVIP will assign the first NP stimuli (input as a result of parameter card "STIMUL" to be used as prototypes as well as stimuli. The distance matrix will then be the distance of the stimuli from each other if NP = NV. If NP is less than NV, the distance matrix will not be square.

11-15 The number of components NC in each vector representing the prototypes. Right justify in column 15. Must be the correct value if NP is greater than zero; otherwise leave blank.

20 Enter the logical file number NT from which the prototypes will be obtained. NT must be either 4, 5, or blank. If NT is blank or 5, the prototypes are obtained from the card reader. If NT is 4, logical TAPE 4 is used. NT is not used if NP is less than or equal to zero or if TSK =  $\emptyset$ .

21-80 Enter the format to be used in reading the prototypes from file NT. If columns 21 through 30 are blank, the default format (5E15.8) is used. If "NONE" is entered in columns 22 through 25 (column 21 is left blank), the file is assumed to be unformatted.

Input of data is via subroutine PICK. The use of a blank or of "NONE" does not change the default format. All other entries change the default format to the new entry which will be the default format for succeeding parameter cards.

NEW CARD	1-3	Enter the alphanumeric used to represent the first prototype.
NO TITLE		
(Use Only if NP is not $\emptyset$ and TSK > $\emptyset$ )	4-6	Same as above for the second prototype.
	7-9	Same as above for the third prototype.
	...	etc.
	...	
	...	
76-78		Same as above for the 26th prototype; continue on succeeding cards as necessary. Use the

same columns 1 through 78 until NP alpha-numerics have been defined.

STIMUL	1-6	Enter "STIMUL"
	7-10	Enter the number of stimuli NV to be read. Right justify to column 10. If the NP prototypes are to be used as stimuli, set NV = 0 or leave blank (note that NP must be greater than zero for this option).
	11-15	Enter the number of components NC in each vector representing the stimulus. Right justify to column 15. If NC was nonzero on the PROTYP card, NC must be the <u>same</u> on both cards. NC = 0 or blank implies that the spatial filtering has not been accomplished and NC will be determined in subroutine VRF. Note that NC is not the number of elements in the stimulus array. NC is the number of components in the vector representing the stimulus subsequent to the spatial filtering.
	20	Enter the logical file number NT from which the stimuli are to be obtained. NT is not used if NV = 0.
		5--(Or a blank) If stimuli are to be read from the card reader.
		4--If stimuli are to be read from a magnetic tape or mass storage device.
		9--If stimuli have been coded in an octal format and are contained on cards to be read from the card reader. This option is used only if the input stimuli are formed by a set of 1s on a background of zeros and are in an octal format. This format must be such that each row of the stimulus array is packed into a single word. This option is also restricted to MJ = MI = 32 with an octal format of (7011) and for MJ = MI = 64 with an octal format of (4020). When MJ = 64 PICK fills in the right most 4 columns of the array with zeros since the CDC 6600 computer word contains only 60 bits. PREVIP resets the NT = 9 to NT = 5 and the cards are read from the card reader.
	21-80	Enter the format to be used in reading the stimuli from file NT. If columns 21-30 are blank, the default format (5E15.8) is used

unless it has been changed by the PROTOT card.  
If "NONE" is entered in columns 22-25, the  
file NT is read as an unformatted file. If  
NT = 9, either "(7011)" or "(4020)" as appro-  
priate, must be used.

NEW CARD	1-3	Enter alphanumeric for first stimulus.
NO TITLE		
(Do Not Use if NV = 0)	4-6	Enter alphanumeric for second stimulus.
	...	etc.
	...	
	...	
	76-78	Enter alphanumeric for 26th stimulus.
		Continue on succeeding cards as necessary using same columns.
DSMATX	-6	Enter "DSMATX"
	10	Enter the distance matrix printout parameter MTX. The options are: 1--To printout the distance matrix only. 2--To printout the ordered distance matrix only. 3--To printout both matrices. 0--(Or a blank) To printout neither.
	15	Enter the punched card output options desired: 1--For creation of a formatted file (TAPE 3) which contains the contents of the distance matrix created by subroutine DSCOMP. The program stops after creating the formatted file. The user makes use of a control card to copy this file onto a punch file; i.e., on the CDC 6600 system, use "COPYBF" (TAPE 3, PUNCH) after the execution card. 2--Same as 1 except TAPE 3 contains the ordered distance matrix created by subroutine ORDER along with the ordering sequence. The file organization is as follows: the set of cards giving the ordering sequence for the closest prototype to the first stimulus

through the furthest prototype from the first prototype in format 2613. Next, a set of cards for the corresponding distances in format 6E13.6 or in the format specified in columns 21-20 of this parameter card. Next, the above sequence is repeated for the succeeding stimuli. The program stops after creating TAPE 3.

	21-20	Enter a blank for a default format of (6E13.6) or enter any other valid format starting in column 21.
CONFUZ (Not Needed if TSK = 0 or blank)	1-6 9-10	Enter "CONFUZ"  Enter 1 if distance histogram is desired after each of the NS removals. Leave blank otherwise.
	14-15	Enter NS the number of stimuli to be removed from the symbol set. Subroutine CONFUS removes the worst NS stimuli (one at a time) and shows the improvements at each step.
	19-20	Enter ICU the number of worst symbols to be modified in such a manner as to improve the symbol set. This option is not yet ready; therefore, leave blank.
PROBAB (Not Needed if TSK = 0 or blank)	1-6 10	Enter "PROBAB"  Enter 1, 2, or 3 to convert the distance matrix to a probability of error prediction matrix. Enter 0 or a blank if no further processing.  1--Results in a printout of the probability of error prediction matrix.  2--Results in a printout of the ordered error prediction matrix.  3--Results in printout of both matrices.
	15	Enter the logical file number (NT) to be used to input the probability of error estimates based on human performance. This data is used in subroutines PRDCOR and RNKCOR. See card entitled PROTPY for details on NT.
	20	Enter 0 or a blank if probability estimates based on human response data are not available. Enter 1 if the data is not available.

Enter 1 if the data is available and the product and rank correlations are to be computed.

21-80

Enter the format to be used in reading the human response data from file NT. If columns 21-30 are blank, the default format (5E15.8) is used unless changed by "PROTYP" or "STIMUL" cards. If "NONE" is entered in columns 22-25, the file is assumed to be unformatted.

### DATA DECK ORGANIZATION

The data deck is composed of the parameter cards appropriately interspersed with the data input to the program. The organization is as follows:

1. PROBLM card (identifies job by a problem title)
2. TASKNB card [defines tasking (T&K) and intensity plot options]
3. Untitled visual field definition card
4. PROTYP card (defines NP, NC, VT, and format)
  - 4a. Untitled prototype table card (a). Used only if NP is not zero and TSK is greater than zero.
  - 4b. Prototype vectors in the proper format. Used only if NP is greater than 0, TSK is greater than 0 and NT is blank or 5. Note: If TSK is 2, 3, or 4, NC must be defined to be equal to the number of components in the vector representing the prototypes.
5. STIMUL card (defines NV, NC, NT, and format)
  - 5a. Untitled stimulus label card(s). Used only if NV is greater than zero.
  - 5b. Digital representation of the stimuli to be processed by the algorithm in the required format. Used only if NT is blank or

NT = 5 and NV is greater than zero. Note: If TSK defined by TASKNB is -1, 2, 3, or 4, enter the vector representations of the filtered Fourier Transform of the stimuli (in lieu of the digital representation of the stimuli). Condition on NV and NT still hold. Also, NC must be properly defined.

6. DSMTX card (defines the distance matrix printout options)
7. CONFUZ card (define CONFUZ subroutine options)
8. PROBAB card (defines probability computation options, NT, and format for human estimates).
- 8a. Human response data in required format. Listed in the same sequence as the prototypes are ordered. The responses to each given prototype should be listed and followed by the responses to the next prototype. These cards are used only if NT = 5 and column 20 of PROBAB is = 1 or -1. Note: The program converts these responses to probability of error estimates if the diagonal terms of the human response array is nonzero. If they are zero, the algorithm assumes that the array is a probability of error array. The conditions on NT and column 20 still hold.

#### PREVIP FLOW CHART

PREVIP is flow charted in Figure 8.

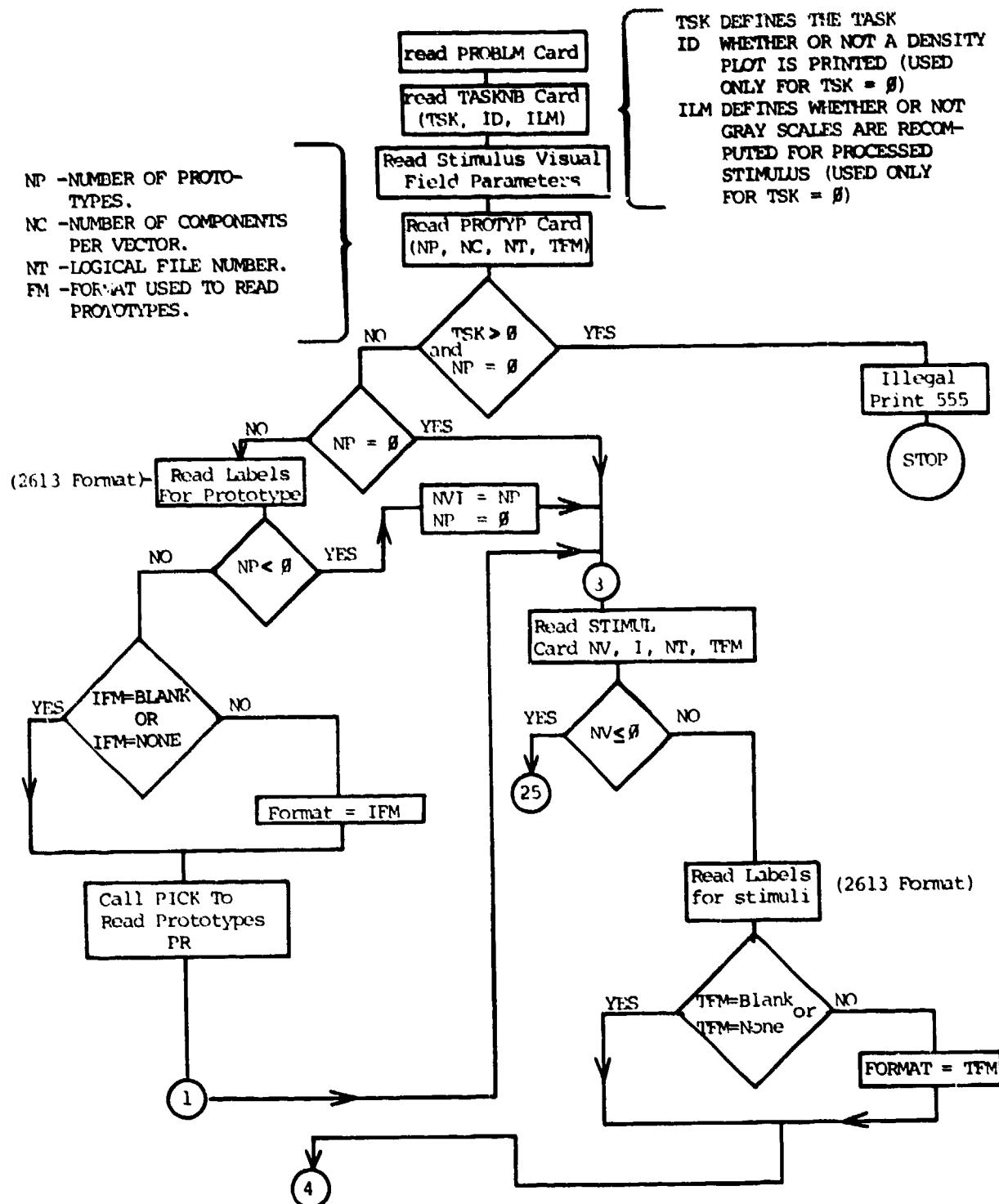


Figure 8. PREVIP Flow Chart

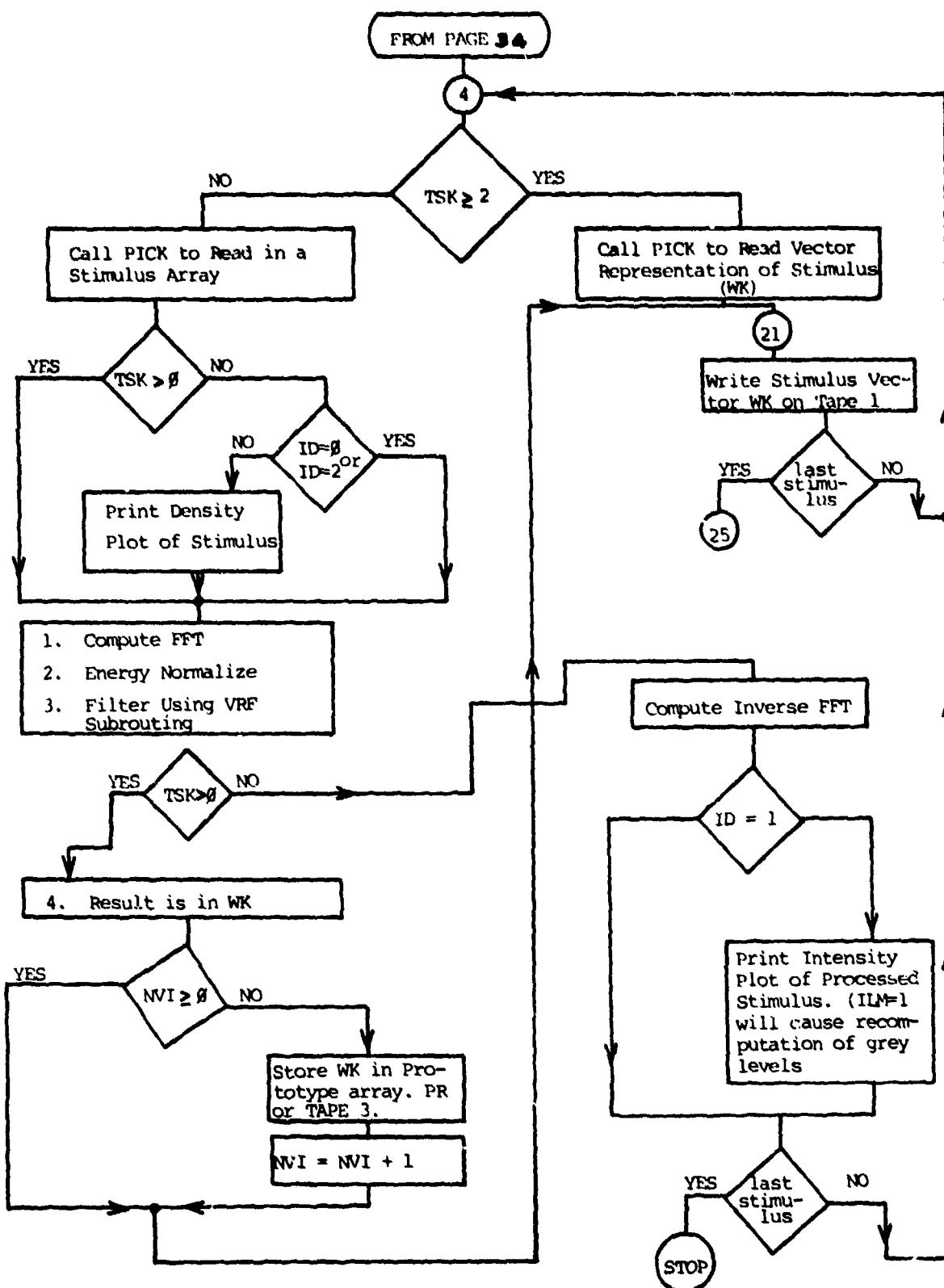


Figure 8. PREVIP Flow Chart (continued)

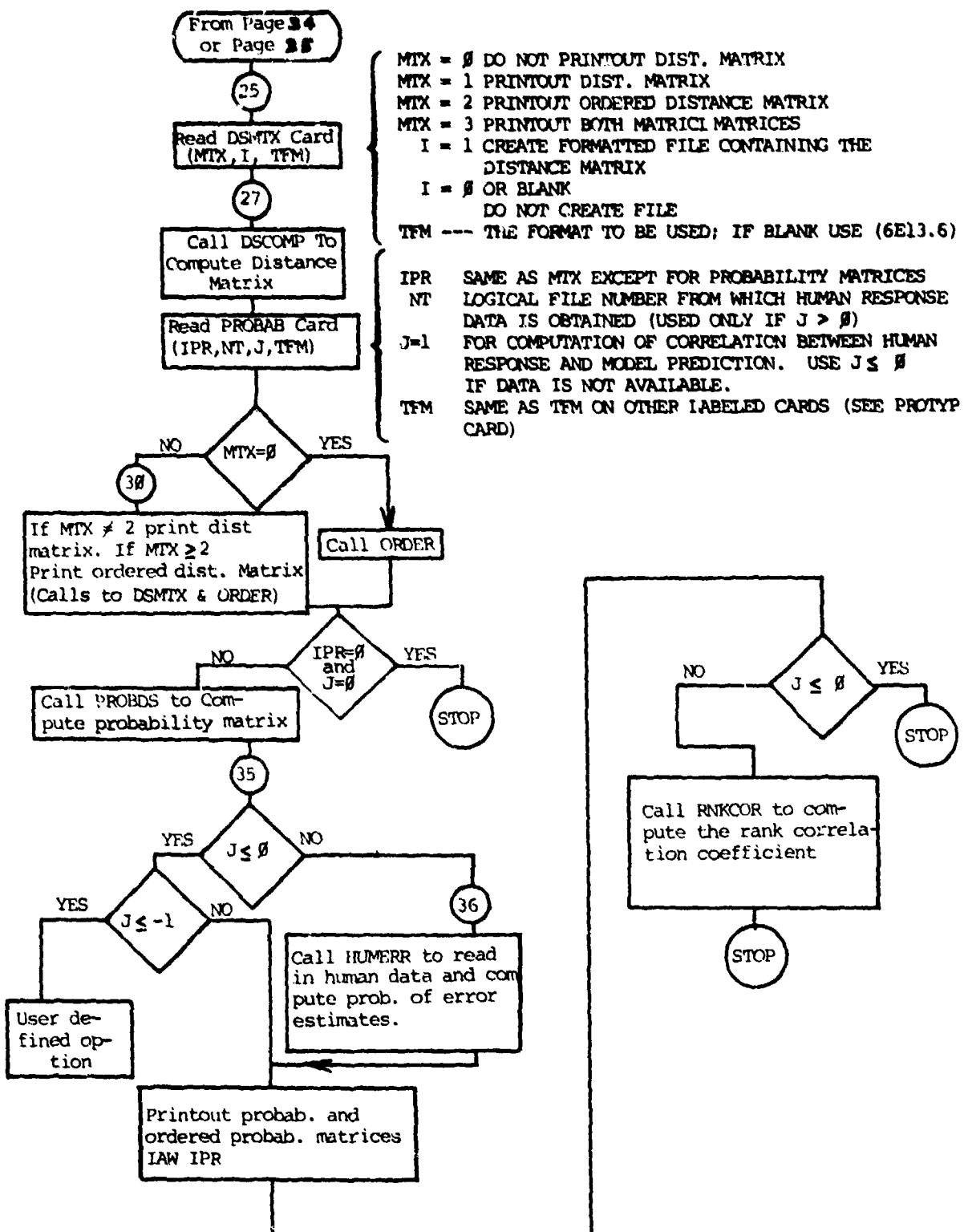


Figure 8. PREVIP Flow Chart (continued)

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